Modeling Shading Losses for PV Systems in SAM

SAM 2014 Webinar Series

Aron Dobos

August 27, 2014

SAM Webinar Schedule for 2014

Schedule

- **New Features in SAM 2013 and Beyond**
  - October 9, 2013: Paul Gilman
- **SAM PV Model Validation using Measured Performance Data**
  - December 11, 2013: Janine Freeman
- **Solar Resource Data 101**
  - February 12, 2014: Janine Freeman
- **Analysis of Electricity Rate Structures for Residential and Commercial Projects**
  - April 16, 2014: Paul Gilman
- **Modeling Parabolic Trough Systems**
  - June 18, 2014: Michael Wagner
- **Modeling Shading Losses for PV Systems**
  - August 27, 2014: Aron Dobos

Details

- All sessions last one hour and begin at 1 p.m. Mountain Time
- You must register to participate
- Registration is free, but space is limited
- More details and registration information on Learning page of SAM website
- All webinars are recorded and posted online at the link below for viewing at your leisure
- Schedule for 2015 webinars will be available soon

https://sam.nrel.gov/content/resources-learning-sam

Webinar Outline

- **Review of options for shade modeling**

- **Introduction to the SAM 3D Shade Calculator**

- **Live demonstration of setting up a system with shading obstructions**

PV Module Database Comparison

- All PV tools rely on databases of coefficients that represent the modules. ***Are these databases the same?***

- Compared 4 databases (Sandia, CEC, PVSyst, PVSOL) across 5 variables (Voc, Imp, Vmp, Isc, Pmp)

- Found 61 module models in common

- Found minimal variance within those 61 module models

- The individual module variance shows certain variables for a few panels have more than 3% but less than 3.5% standard deviation.

- Slight variation between technologies (thin-film higher).

Complete webinar with slides available on the SAM website:
https://sam.nrel.gov/node/69092
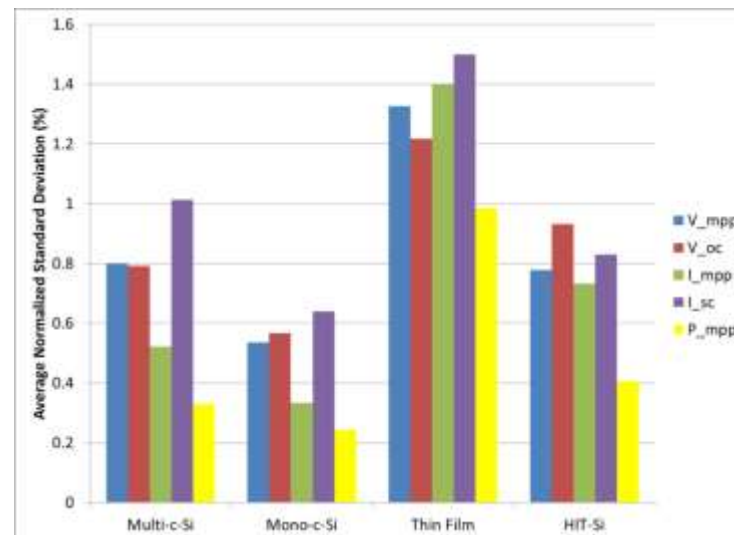
Module Families		
Aleo S16 165	Mitsubishi PV-MF180	SunPower SPR-205
Aleo S16 170	Mitsubishi PV-UD185MF	SunPower SPR-210
Aleo S16 175	Mitsubishi PV-UD190	SunPower SPR-215
Aleo S16 180	Moser Baer MBPV 220	SunPower SPR-220
Aleo S16 185	Sanyo HIP-186	SunPower SPR-225
BP Solar BP3220	Sanyo HIP-190	SunPower SPR-230
BP Solar SX3190	Sanyo HIP-195B	SunPower SPR-300
BP Solar SX3195	Sanyo HIP-200	SunPower SPR-305
BP Solar SX3200	Sanyo HIP-215	SunPower SPR-315
Canadian Solar CS5P/CS6P-220M	Sanyo HIP-225	Suntech STP170S
First Solar FS-267	Sharp ND-123	Suntech STP175S
First Solar FS-270	Sharp ND-160	Suntech STP180S
First Solar FS-272	Sharp ND-167	Suntech STP200S
First Solar FS-275	Sharp ND-187	Suntech STP260S
Kyocera Solar KC130	Sharp ND-208	Suntech STP270S
Kyocera Solar KD135GX	Sharp ND-216	Suntech STP280S
Kyocera Solar KD180GX	Sharp NE-165	Yingli YL210
Kyocera Solar KD205GX	Sharp NE-170	Yingli Solar YL220
Mitsubishi PV-MF165	Solar Semiconductor Inc. SSI-M6-220	Yingli Solar YL230
Mitsubishi PV-MF170	Solar World SW175	
Mitsubishi PV-UD175MF	SunPower SPR-200	

Options for Modeling Shading Losses in SAM

Where to Enter Shading Data?

In the upcoming version of SAM, all shading options are entered on the "Shading" input page

Note: In previous versions of SAM, shading is specified on the "Subarrays" page, but self-shading is specified on the array page for subarray 1.

(1) External Shading Factors

- **This option can be used for any type of system (residential, commercial, utility-scale), but you need to get the shading information from other software or measurements**
  - Hourly beam irradiance shading loss percentages (rarely available)
  - Table of shading losses by month and hour of day (most popular)
  - Table of shading losses by solar azimuth and altitude (occasional)
  - Constant diffuse shading loss (occasional)

- Import shading losses calculated in an other program, such as Pvsyst

- Import shading losses calculated by an onsite survey, such as with a Solmetric SunEye or SolarPathfinder device

Edit shading data

Import shading data from external tools

| PVsyst near shading... | SunEye hourly shading... | SunEye obstructions table... | SolarPathfinder month by hour shading... |

- Enable hourly beam irradiance shading factors
- Enable month by hour beam irradiance shading factors
- Enable solar azimuth by altitude beam irradiance shading factor table
- Enable sky diffuse shading factor (constant)

OK   Cancel

(2) Self-shading Calculator

- **Use for larger commercial rooftop and utility scale installations arranged in a regular pattern when one row shades the next**

- **For smaller residential systems with self-shading that may or may not be regular, you can use the shade calculator (next slide)**

  o Applicable to fixed tilt or one axis tracking arrays

  o You specify:

    – Landscape or portrait orientation of modules

    – Number of modules along side of row

    – Number of modules along bottom of row
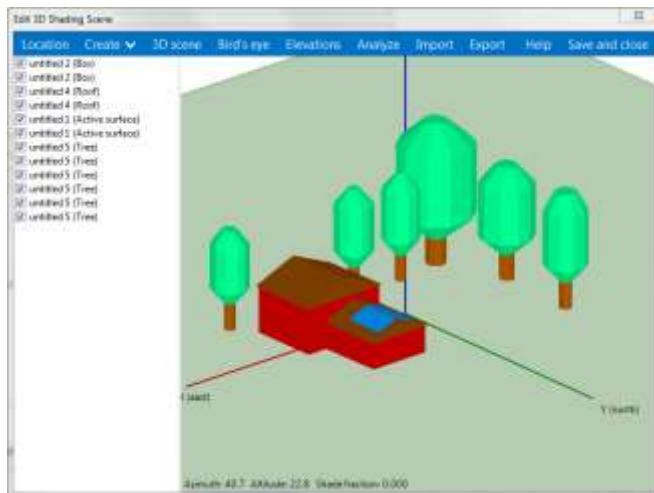
    – Row-to-row spacing

  o Example fixed system:
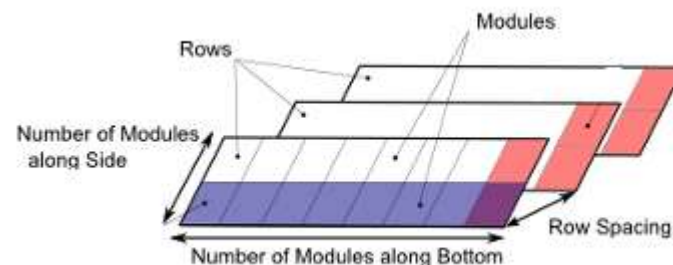
Deline, C.; Dobos, A.; Janzou, S.; Meydbrey, J.; Donoval, M. (2013) A Simplified Model of Uniform Shading in Large Photovoltaic Arrays. Solar Energy Vol 96, October 2013, pp 274-282

(3) SAM 3D Shade Calculator

- **We've added a 3D shading calculator in the upcoming version of SAM.**

- **Allows you to create a 3D scene and will calculate a month-by-hour shading loss table.**

Introduction to SAM
3D Shade Calculator

Background

In 2013, the SAM team invited a technical review committee to provide recommendations for future improvements to SAM's PV model.

The highest priority identified by the TRC was the need for a way to calculate shading losses from using a 3D representation of the system.

The Department of Energy agreed to fund this project and it will be available in the upcoming version of SAM.

Blair, N.; Dobos, S.; Janzou, S.; Gilman, P.; Freeman, J.; Kaffine, L. (2013). SAM Technical Review Committee Final Report: Summary and Key Recommendations from the Onsite TRC Meeting Held April 22-23, 2013. 25 pp.; NREL Report No. TP-6A20-58785. (PDF 628 KB)

Overall Goals for Our Tool

1. Enable experienced PV modelers, researchers and students to perform basic analysis of shading impacts on PV power production for a particular scene

2. Provide a free and independent tool that can be used to compare against other tools to hopefully identify and problems and improve the accuracy of all available models

3. Be able to read and write common file formats for data that can describe 3D scenes and enable data interchange between existing tools for shading scenes

4. Enable the SAM team to do additional research into shading calculations

5. Enable shading analysis for solar water heating systems as a side benefit

Availability:

1. Beta version available since May for standalone tool. Download from

http://sam.nrel.gov/shade

1. Will be integrated into the upcoming version of SAM

(1) Objects in a Scene

- **The scene consists of "active surfaces" (photovoltaic subarrays) and shading obstructions.**

- **Four three-dimensional shapes are designed to represent most shading objects: Box, cylinder, tree, and roof.**

- **You can combine these basic objects to create more complex obstructions.**
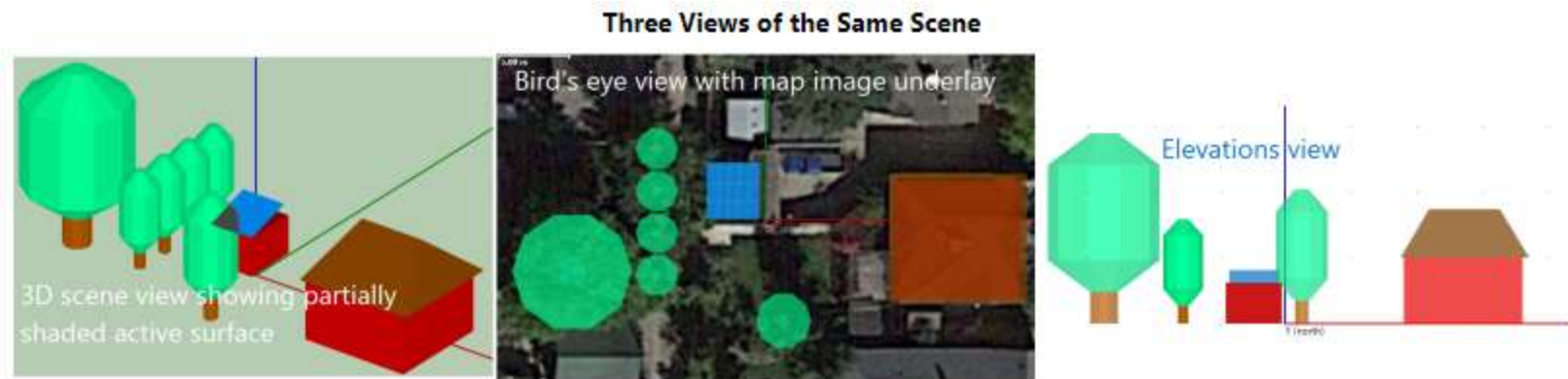

Scene with Four Active Surface Objects
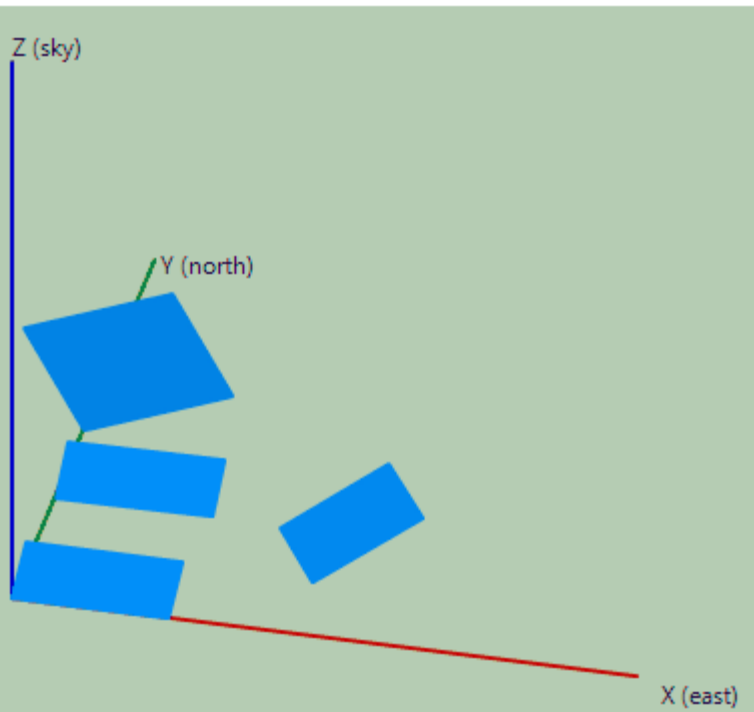
Scene Showing the Five Shading Object Shapes
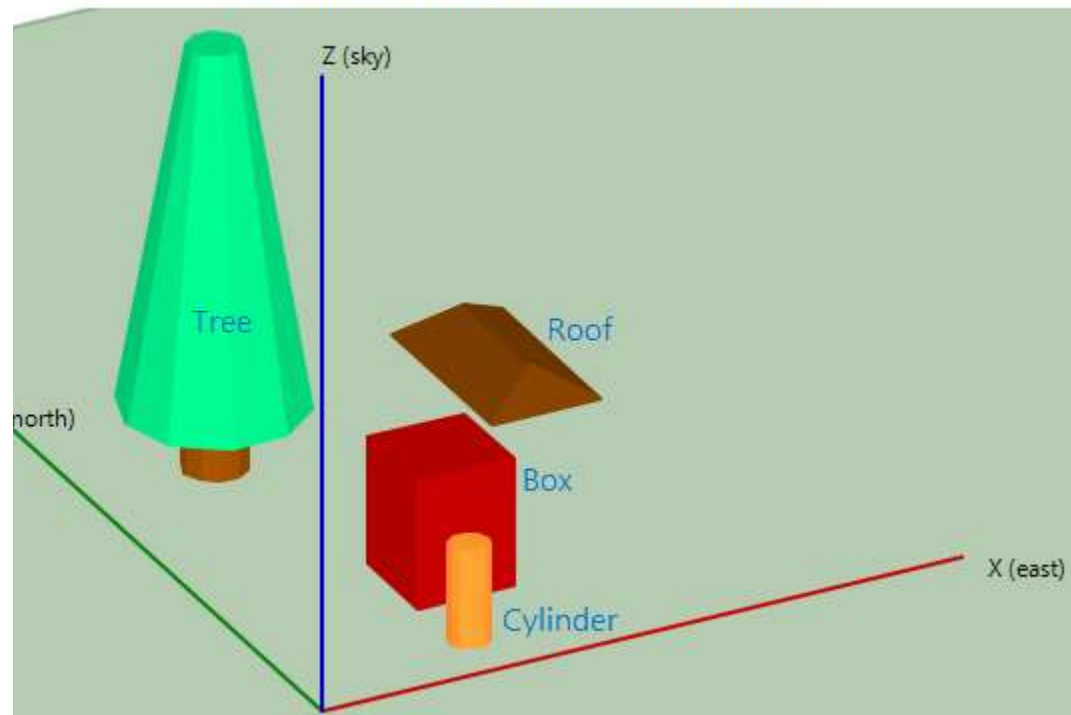
(2) Viewing the Scene

• **View and edit the 3D scene in three-dimensional, bird's eye, and elevation views.**

• **Add an optional aerial photograph from online maps or your own image as an underlay for the bird's eye view to help position objects on the scene.**


Three Views of the Same Scene

- **The 3D View is used to visualize the scene with shade at different sun positions, as well as select objects with the mouse**
- **In the birds-eye view, objects can be moved and resized in the X-Y plane**
- **In the elevations view, the height of objects can be changed and moved in the Z-X plane.**

(3) Location

• **Uses geocoding to automatically find latitude, longitude, and time zone for any street address, as well as download a map underlay to help with positioning objects in the 3D Scene.**
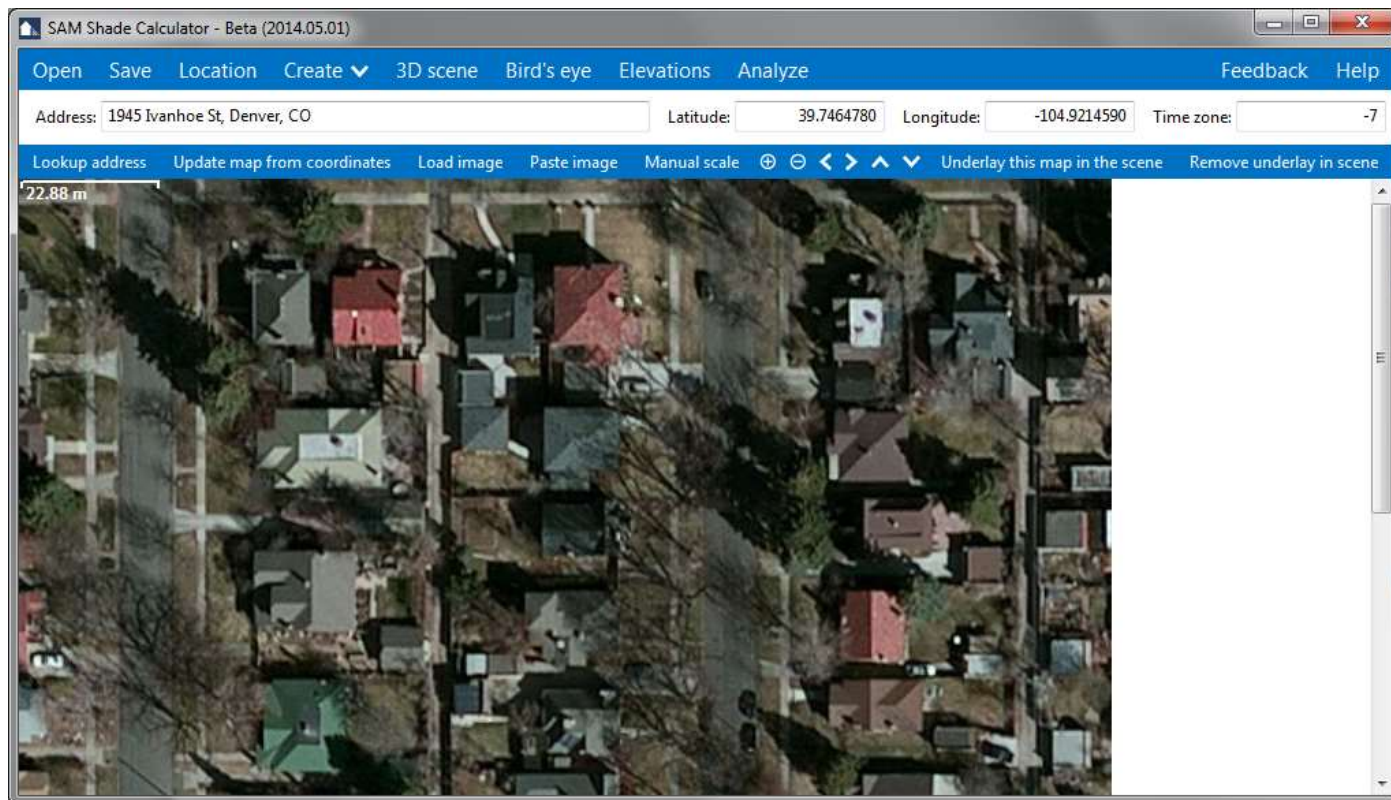
Usage note: Correct location information is required to correctly calculate sun positions for your location. When you create a new shading scene in SAM, the coordinates of your weather transfer automatically, but if you change weather files, you'll need to update the coordinates in the shading calculator too.
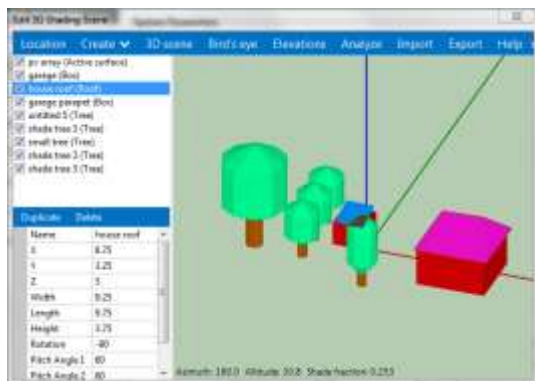
(4) Outputs

- **Calculates a month x hour table of shading losses.**

  - The shading loss represents the obstruction of beam irradiance on the array at each point in time.

  - The values in the table are calculated at the midpoint of each month.

  - The losses are linear with shade area. This is an approximation, and depending on the system configuration, may underpredict losses due to shading when nonlinear mismatch losses are present.

- **Option to calculate hourly shading losses for the whole year.**

- **For systems with multiple subarrays, a shading loss table for each subarray can be calculated independently.**

Comparison to Measured Data

We modeled three systems in the SAM 3D Shade Calculator for which we had onsite Solmetric SunEye measurements, and compared the modeled energy losses on an annual basis using both types of shading estimates.

Results:

System	Location	System Size	Baseline kWh Annual	Lost energy (via SunEye)	Lost energy (via 3D)	Difference in energy loss estimates
Ivanhoe	Denver	3.6 kW	5478	738	785	6.37%
Babbitt	Los Angeles	4 kW	5659	326	296	9.2%
Halstead	Los Angeles	4 kW	6427	361	329	8.86%

The shading calculator is roughly within 10% of onsite measurements. We feel that this is quite good because of the relatively high uncertainties inherent in onsite measurements as well as challenges in recreating a 3D scene perfectly in a model.

Live Demonstration

Step-by-Step Instructions

1. Open SAM, and create a Photovoltaics + Residential case.

2. Select Denver Intl Ap (TMY3) as the weather site.

3. Leave the default module and inverter selections alone.

4. Note the default system design for 4 kW, south facing, 20 degree tilt.

5. On the shading page, turn off the self-shading calculator.

6. Click 'Open shade calculator…'

7. Since a scene hasn't been entered before, the location information is transferred to the 3D editor. Click OK on the dialog to continue. If you change the weather file, you'll need to manually update the location information in the shade calculator too.

8. Verify the information on the 'Location' page.

9. Enter 1945 Ivanhoe St Denver CO into the address box, and press Enter. The latitude, longitude, and time zone information will update, and you will see a map of the location appear.

10. Click 'Underlay this map in the scene' to transfer the map to the birds-eye view.

11. Press Ctrl while clicking and dragging the mouse to zoom in and out. Press Shift while dragging the mouse to pan the view.

12. From the 'Create' menu, select 'Box'.   Using the handles displayed (magenta circles) drag and reshape the box over the array, to represent the garage.

13. Switch to the elevations view, and reduce the height of the box to make it roughly a cube. You can verify your work in the 3D view.

14. Create a tree object. By default, the tree might be large or small depending on the scale of the image, so size it in the bird's eye and elevations views to match. Duplicate the tree to create several obstructions around the garage.

15. Create an active surface. In the elevations view, position it on top of the garage in the Y-Z plane.

16. In the birds-eye view, size and position it as a small array roughly covering the top of the garage.

17. Finally, using the property editor, change the tilt angle to 20 degrees, in accordance with the value on the System Design page.

18. Switch to the 3D view to confirm the 3D scene. Rotate the scene by dragging the mouse. The perspective is from the point of view of the sun. When an objects shades the active area, it will show up as a grey shaded area, and the fraction of the active area that is shaded is shown at the bottom of the display.

19. On the Analyze page, click "Diurnal Analysis". The shading factor table will be calculated. You can export this table or Send it to Excel, and use it in SAM or other tools.

20. Using the integrated shading analysis tool in SAM, press "Save and Close". Pressing this button stores all of the 3D scene data as part of the SAM project file, reruns the diurnal analysis, and aks you whether to update the month-by-hour shading losses for Subarray 1.

21. Press Yes to overwrite the shading factor table under the "External Shading" category, in the month –by – hour option.

22. Now, click the 'Edit shading' button under subarray 1, and you will see the shading losses automatically transferred from the 3D shading tool.

23. Click 'Simulate' to run the system and look at the annual energy. You can optionally return to the shading input page, disable the month by hour factors, and compare the modeled annual energy production with and without shading losses.

Other topics not covered: Naming objects , creating complex roof shapes, tree shapes , using custom underlay images in bird's eye view, handling multiple subarrays with different orientations, importing and exporting .s3d scene files, hourly loss analysis .

Future Plans

- **Import and export 3D scene in various formats**

- **Estimation of diffuse irradiance losses due to view factor reduction**

- **Scripting support**

- **Estimation of nonlinear losses using an empirical loss model**

- **Support for 1- and 2-axis tracking systems**

Questions?

Download standalone beta version:

http://sam.nrel.gov/shade